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*Chapter Eighteen*

# GEOTECHNICAL INFORMATION FOR DESIGN

Chapter Eighteen briefly discusses the elements of geotechnical engineering the designer will typically be required to address during the design of a project. Chapter Eighteen does not address the analyses and procedures conducted by a geotechnical consultant or the Materials and Tests Division's Geotechnical Section during their investigation. Where questions arise, the designer should review the geotechnical report and/or contact the geotechnical engineer for guidance.

## *18-1.0 GEOTECHNICAL REPORT*

The geotechnical report presents the data obtained during the geotechnical investigation. It also summarizes the engineering analyses conducted and provides recommended treatments for the various soils and conditions encountered on the project. The following sections discuss the information that may be included in a geotechnical report.

### 18-1.01 General Information

The geotechnical report will include the following general information.

1. Project Description. The report will identify the location of the project (including the beginning and ending stations), provide a project identification description and define the scope of the proposed construction.

2. Field Investigations. The report will summarize the field and laboratory investigation procedures used on the project. It should also include the date when the field investigations were conducted.

3. Environmental Conditions. Include a list of environmental conditions that could have affected the results (e.g., climatic conditions) in the report.

4. Geological Information. The beginning of the report will include a general description of the geology and soils encountered on the project. It should also provide a description of the

terrain including drainage patterns, ground water elevation, bedrock information and any other specific conditions that may have value in the design of bridges, culverts and other structures.

## <u>18-1.02 Detailed Geotechnical Conditions and Recommendations</u>

This portion of the geotechnical report should provide a discussion on specific problems or conditions that may affect the design or construction of the project. The report will discuss the following.

1. <u>Features</u>. The report will provide a detailed description of the conditions found on the project, organized according to areas of similar soils and terrain features. It will identify the types of soils found, strengths and their location.

2. <u>Recommendations</u>. The report should provide recommendations concerning potential design and construction problems for earthwork, pavements, bridges, retaining walls, culverts, sign supports and other structures. Where applicable, the report should provide the recommendations as follows:

    a. special embankment construction;

    b. cut slopes in soil or rock;

    c. how to treat unsuitable materials in subgrades (e.g., removal, replacement, special treatment such as lime, cement or flyash stabilization, etc.);

    d. rock swell factors;

    e. special drainage installations;

    f. use of special channel lining materials;

    g. landslide corrections;

    h. wet soils;

    i. embankment construction using recycled waste materials;

    j. embankments over landfills;

k. foundations; and/or

l. dewatering.

3. Field Equipment. The report will list where field monitoring equipment and/or devices (e.g., piezometers, settlement plates, shoulder stakes, toe stakes) are required. The report will list the following:

   a. purpose and/or objective of the equipment;
   b. proposed locations;
   c. approximate schedule for the frequency of readings; and
   d. any special construction controls.

   The designer must note the location and number of the field monitoring equipment to be installed. They should be included in the construction plans, in a tabular format, in the itemized proposal and in the specifications.

4. Boring Logs. Boring logs will be included in the appendix of the geotechnical report. These will be based on field logs and laboratory test data. Boring logs are generally available in an electronic format for in-house projects.

## 18-1.03 Test Data and Engineering Analyses

The report will summarize the field and laboratory investigation procedures used in the investigations. Results of the laboratory tests on various samples will be included in the appendix of the geotechnical report in a tabular format. Each sample will be identified according to its sample number, boring number, location, depth and results from any testing. Separate tabulations will be included for classification test results, strength test results and other special test results.

The work described in this section will include a review and correlation of the various test results for embankment stability, material placement and other geotechnical engineering considerations. Sketches, assumptions, calculations, etc., will be provided in the appendix of the report. Some analyses that may be included are as follows:

1. settlement analysis;
2. sand drain analysis;
3. sliding block slope stability analysis;
4. rotational slope stability analysis;
5. bridge foundation analysis for each bridge foundation; and/or
6. retaining structure analysis.

## 18-1.04 Geotechnical Profile

The geotechnical profile, when required, shows the geotechnical information on a set of plans. The following is applicable design and construction information that may be included in the geotechnical profile.

1. Soil Test Data. Soil test data will be tabulated on separate sheets. This may include the information as follows:

    a. laboratory sample number;
    b. field sample number;
    c. boring number;
    d. station;
    e. offset;
    f. depth of sample;
    g. pH;
    h. textural or grain size classification;
    i. AASHTO classification;
    j. test results obtained from mechanical analysis;
    k. liquid limit;
    l. plastic limit;
    m. plasticity index;
    n. maximum dry density;
    o. optimum moisture content;
    p. CBR;
    q. loss on ignition; and
    r. calcium and magnesium.

2. Boring Locations. The boring locations will be plotted on the plan view. Elevation of subsurface water during boring, at the completion of boring and 24 hours later, will be shown on the profile sheets. The location and depth from which test samples were obtained will be indicated and referenced to the Soil Test Data Sheet.

3. Unsuitable Materials. The locations of unsuitable material will be shown in the plan and profile views and/or in the cross section sheets. This may include peat, unstable soil, wet soils, etc.

4. Soundings. If soundings are made, these may be plotted on plan and profile or cross section sheets. The limits of peat or unsuitable material to be removed, the proposed grade line, rock line, etc., will be plotted on the sounding profile and cross section sheets.

### 18-1.05 Incorporation of Geotechnical Report Into Contract Documents

A copy of the geotechnical evaluation report summary should be included in the contract proposal documents. In-house reports prepared by the Materials and Tests Division's Geotechnical Section, excluding boring logs, drawings and test data, should be included in their entirety in the contract documents, as the extent of the report's text is generally only a few pages.

The designer should place a quality paper copy of the Department-prepared geotechnical report or a geotechnical report summary into the contract document file as is presently done for the environmental permits.

## *18-2.0 APPLICATIONS*

There are numerous areas throughout Indiana where the designer may need to consider special subsurface treatments. Figure 18-2A, Indiana Counties with Special Geotechnical Concerns, identifies the counties where the designer may encounter coal mine subsidence, peat, sink holes (karst areas) and slide conditions. For most projects, the geotechnical report will identify if the project has any special requirements, and it will recommend possible solutions. The following sections provide basic information and guidance for treatment of common geotechnical elements the designer may encounter.

### 18-2.01 Coal Mine Subsidence

Coal mine subsidence occurs when the effects of roof collapse in underground coal mines reaches the surface or reaches structure foundations. Figure 18-2A, Indiana Counties with Special Geotechnical Concerns, illustrates the counties where coal mine subsidence is a concern. Effects on the surface include sinkholes, sags and troughs. This may result in cracks, breaks and settlement in buildings, roads, structures and utilities and may change surface and subsurface drainage.

For mines less than 45 m deep, roof collapse is very likely to cause surface effects. Mines deeper than 45 m seldom show sudden, dramatic, surface collapse such as sink holes, but generally cause sags and troughs and can cause cracks and breaks in structures, etc.

The added weight of new embankments and structures can cause collapse of coal mine roofs that had been near the breaking point already. Other factors such as drainage changes and earthquake acceleration coefficients (in structure design) increase the probability of more collapse and subsidence.

Subsidence prevention treatment for design of bridges and structures on deep foundations can include drilled shaft, predrilling to depths below the mined elevations to set pile tips, or injection of grout to fill the voids to prevent collapse. Treatment for roadways and embankments could include grout injection to prevent subsidence and use of lightweight fill. Post-construction treatment can be wedge-and-level patching to eliminate abrupt dips. Sinkhole-type failures can sometimes be treated as in Karst sinkholes, see Section 18-2.07. Monitoring for subsidence can be done with settlement stakes and plates.

## 18-2.02 Erosion Control

Erosion can occur from both surface water flow and subsurface seepage and drainage. Soil susceptibility to surface erosion is primarily a function of the water flow and the gradation and plasticity of the soils. There are several methods to protect soils from surface flows, and each site must be treated on a case-by-case basis. The possible options include the following:

1. removing the erodible materials and replacing them with acceptable materials;
2. using slope encasement with cohesive soil;
3. using geotextile fabrics with riprap (see Section 18-2.08(05));
4. providing erosion mats;
5. planting vegetation;
6. reducing side slopes;
7. providing sediment basins;
8. constructing special drainage channels and ditches; and
9. providing closed drainage systems.

Chapter Thirty-seven provides additional guidance on the design of temporary erosion control methods during construction.

Erosion by subsurface flows may also be a problem if soil particles are transported by the water flow. Protection against subsurface erosion is generally treated with spring boxes or with granular filter materials or filter fabrics which have particles or perforations sized to satisfactorily pass the water flow without permitting movement or loss of the soil particles.

## 18-2.03 Geotextiles/Geogrids

Geotextiles/geogrids have been proven to be an effective solution to solving many geotechnical problems. They can be used as follows:

1. to stabilize weak and saturated subsoils under pavement surfaces;
2. between pavement layers to reduce cracking and to provide a moisture barrier;
3. as a soil filter for subsurface drainage (e.g., underdrains along pavements, behind retaining walls);
4. as part of an erosion control system (e.g., under riprap, as a sediment fence);
5. as part of a soil retaining wall;
6. as slope reinforcement;
7. as a separator layer; and
8. to minimize differential settlement.

The geotechnical report should identify the locations where geotextiles or geogrids should be used. The designer should contact the Geotechnical Section for specifications and guidelines on the design and placement of geotextiles and geogrids.

## 18-2.04 Landfill Treatments

Landfills are man-made features which generally provide unsuitable material for the roadway substructure. The geotechnical report should identify the location of any landfills on the project and any proposed treatment. If cost effective, the most desirable option will be to excavate the landfill and replace it with acceptable backfill. However, other options may be more feasible, including surcharging, using lightweight fills, using geotextiles, or providing ground modifications (e.g., dynamic compaction, stone columns).

## 18-2.05 Landslides

The term landslide is used to denote the movement of a mass of rock, debris or soil down a slope. The type of landslide can be further defined by characteristics such as the materials in the slide, speed of the landslide and the type of movement. Figure 18-2A, Indiana Counties with Special Geotechnical Concerns, identifies the Indiana counties where landslides may be a problem. The geotechnical report should identify the sites where landslides may be a concern.

Landslides may occur under numerous different conditions man-made (e.g., adverse grading, adjacent construction, vibration from nearby vehicles) or natural (e.g., erosion, earthquakes, precipitation and runoff). Because of the nature of soils and the geologic environment in which they are found vary from site to site, acceptable mitigation procedures will be determined on a site-by-site basis. The designer should review the geotechnical report to determine the appropriate measures to mitigate the landslide potential.

## 18-2.06 Peat Treatment

Peat soils are those soils with a high organic content. Where the organic content is approximately 10% by weight, it typically poses a stability problem and will require special consideration. There are several options for treating peat soil. Two common solutions are to completely remove and replace the peat soil with acceptable foundation materials or to use lightweight materials to reduce settlement. Peat excavation consists of the necessary excavation and satisfactory disposal of peat, muck, marl or any other similar unsuitable materials in peat deposits together with any overlaying material which is not used in embankment construction.

Where the ground water table is below the bottom of the peat deposit, normal excavation and embankment criteria as stated in the INDOT *Standard Specifications* will typically apply. Where the peat deposits are deep and/or the peat deposit is all or partially below the ground water table, special treatments as discussed in the geotechnical report and INDOT *Standard Specifications* will be required. The limits of peat removal for these sections will usually be established by the 1:1 slope as shown in Figure 18-2B, Peat Excavation, Backfill and Disposal.

When showing peat treatment on the plans, the designer should consider the following.

1. Typical Section. Indicate on the typical sections the removal limits as shown in Figure 18-2B.

2. Plan and Profile Sheets. Show the profile for any peat deposit within the construction limits on the profile sheet. Show this profile with a short dashed line and label it as “Peat Profile on Center Line” or “Peat Profile ___ m Lt. or Rt. of Center Line” as appropriate.

3. Cross Sections. Use solid lines to show the peat excavation limits and peat backfill (B Borrow) limits on the applicable cross sections. Mark the first peat section in any series as such to define these limits. Include the end areas and volumes for peat removal on the cross sections.

4. Approval. Submit all peat disposal plans to the Geotechnical Section for approval.

## 18-2.07 Sink Holes

### 18-2.07(01) General

Sink holes are caused by subsurface voids, which may continue to enlarge, in rocks (primarily limestone) that are subject to dissolution by the passage of moving ground water. Figure 18-2A, Indiana Counties with Special Geotechnical Concerns, illustrates the counties where sink holes may be a concern. Sink holes should be anticipated in any carbonated rock terrain. Known sink hole locations on the project will be shown in the geotechnical report and environmental documents. During a field review, sink holes can be identified by roughly circular, closed depressions at the ground surface. Another identifying feature is where water is flowing into a depression with no outlet. Inspection of topographic mapping and aerial photographs will also assist in the confirmation of sink holes.

The treatment for sink holes will vary from site-to-site based on the location, size of the sink hole and environmental considerations. Sink holes will typically be capped or installed with a chimney. Capped sink holes are filled with material (e.g., rocks, concrete, gravel) and sealed so that additional surface water cannot flow into the hole. See Figure 18-2C, Typical Sink Hole Cap. The chimney treatment encourages surface water to continue to flow into the hole. However, any surface water flowing into the sink hole must be filtered. The Environmental Section should be consulted regarding the filter design and detention requirements. See Figure 18-2D, Typical Sink Hole Cap with Chimney.

### 18-2.07(02) Exploratory Excavation

Exploratory excavation consists of the excavation of overlying soil and rock layers to determine subsurface conditions (e.g., the existence of a sink hole or cavity) and to determine the exact location, extent and size of the sink hole or cavity. Payment for exploratory excavation is to be in accordance with the INDOT *Standard Specifications*. In determining the quantities that should be shown in the plans for exploratory excavation, the designer should discuss the proposed treatment with the district during the field check.

## 18-2.08  Slopes

### 18-2.08(01)  Slope Stability

In general, earth slopes which are 2:1 or flatter generally will not require any additional special considerations relative to stability.  However, under restricted conditions steeper slopes may be required.  Where steeper embankment slopes are proposed, riprap or other special material may be required to protect the slope from erosion and slippage.  Figure 18-2E, Embankment Treatment, provides general guidelines for determining the thickness of this material based on the embankment height.  Before using steep slopes, the designer should review the geotechnical report or contact the Geotechnical Engineer for additional guidance.  Depending on the rock type, rock cuts may have faces which are nearly vertical. These are illustrated in Figure 18-2F, Typical Rock Cut Benching ($<$ 3.0 m); Figure 18-2G, Typical Rock Cut Benching ($\geq$ 3.0 m); and Figure 18-2H, Typical Soft/Weathered (Rippable) Rock Cut Benching.

### 18-2.08(02)  Transverse Interceptor Drains

Transverse interceptor drains are typically used to collect subsurface water on embankments where the roadway passes from a cut section to a fill section.  Transverse interceptor drains are used to reduce the potential for slope slippage on the embankment.  The geotechnical report should indicate where transverse interceptor drains are required.  See Figure 18-2 I, Typical Transverse Interceptor Drainage.

### 18-2.08(03)  Benching

On embankments, benching is generally used to stabilize proposed fill on existing slopes by excavating the existing material on side slopes to eliminate a plane of weakness or to provide a greater mass of stable material at the toe of slope.  In general, benching should be considered if the existing slope is 4:1 or steeper.  The INDOT *Standard Specifications* provide the criteria for when benching should be provided on embankments.  See Figure 18-2J, Typical Benching Methods, for embankment benching.

Benching in cut sections is generally only provided in rock cut sections to provide debris collection areas for rock slides.  Figure 18-2G, Typical Rock Cut Benching ($\geq$ 3.0 m), and Figure 18-2H, Typical Soft/Weathered (Rippable) Rock Cut Benching, illustrate typical benching procedures in rock cuts. Where soft/weathered rock is encountered, the material is often rippable (machine workable) and does not require drilling and the use of explosives as necessary for hard rock materials.

### 18-2.08(04) Fills on Unsuitable Foundations

In general, where fills will be placed on soft, wet or other unsuitable materials (e.g., peat), these materials should be removed and replaced with acceptable backfill, if economically feasible. Section 18-2.06 discusses the treatment for peat and other similar materials. If it is not economically feasible to remove the unsuitable materials, the use of geotextile fabrics, lightweight fill or other methods may be required. These should be addressed in the geotechnical report. If not, the designer should contact the Geotechnical Engineer for information.

### 18-2.08(05) Guidelines for Placement of Geotextiles Under Riprap on Slopes

Riprap is often placed on embankment side slopes to prevent future erosion problems or to correct existing erosion problems. One of the most cost-effective methods for stabilizing shallow embankment failures is to remove the failed material and replace it with riprap. For all of these applications the embankment should be lined with a geotextile fabric before the riprap is placed. These typically include areas as follows:

1. soil slopes are steeper than 2:1 (below the riprap);
2. there are erodible soils at the interface of the riprap and existing embankment;
3. there is surface runoff flowing through the riprap; and/or
4. there is flow of subsurface water out of the embankment into the riprap.

Where the situation requires riprap and geotextile fabric and where slopes are steeper than 2:1, benching should also be used to anchor the new fill material (riprap). Without benching, the new fill material may slide down the slope at the interface due to a decrease in shear strength of the soil and the infiltration of water. It is recommended that at least one bench be provided at mid height of the slope for embankments of 3 m or less in height. Provide an additional bench for each additional 3 m of embankment height. Additional benches may be required depending on the size of the benches, steepness of the slope and thickness of the riprap. The vertical height and horizontal width of the bench will vary according to the steepness of the slope. Normally the vertical height will be in the range of 0.6 m to 1.5 m.

Where riprap is placed on an existing slope, providing a geotextile fabric under the riprap will facilitate drainage through the riprap without the loss of soil particles at the soil surface due to erosion. The geotextile fabric should be placed as described in the INDOT *Standard Specifications.*

## **18-2.09 Special Soil Treatments**

Some projects may require special treatment of the subgrade to prepare the soil for construction. According to the INDOT *Standard Specifications,* generally the top 600 mm of subgrade below the pavement structure must be compacted to at least 100% of Standard Proctor. Meeting this criteria may involve adding lime, cement, kiln dust or fly ash to the subgrade; constructing drains; or replacing the unsuitable material with special borrow or aggregate. The designer should review the INDOT *Standard Specifications* for additional criteria. The Pavement Design Engineer will make the final determination based on the results of the geotechnical investigations.

## **18-2.10 Structures**

In order for the Geotechnical Engineer to make suitable recommendations for structures, it is essential that the designer provides as much information as practical (e.g., structure configuration, loads). If the designer anticipates needing a working-stress capacity of more than 620 kN per pile, the designer should advise the Materials and Tests Division at the preliminary field check. This working-stress capacity should be noted in the field check minutes. The planning and design of structures (e.g., bridges, retaining walls, sign supports, culverts) requires a determination of the strength of the proposed foundation material. For light to moderate loads, dense soils, rock, stiff clay, etc., may be adequate for shallow foundations. Where there are clearly unsuitable materials or other considerations (e.g., scour potential), the designer may be required to design a deep foundation (e.g., piles) or remove the unsuitable material and replace it with acceptable backfill. The designer should review the geotechnical report to ensure that appropriate materials at the site are available for the proposed foundation design. Section 59-2.0 discusses the types of bridge foundations used by INDOT and the criteria which influence the selection of a foundation type. Chapter Sixty-six discusses INDOT criteria for foundation designs for bridge structures.